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# Does malaria control impact education? A study of the Global Fund in Africa*

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**Abstract**

We examine the middle-run effects of the Global Fund's malaria control programs on the educational attainment of primary schoolchildren in Sub-Saharan Africa. Using a quasi-experimental approach, we exploit geographic variation in pre-campaign malaria prevalence (malaria ecology) and variation in exogenous exposure to the timing and expenditure of malaria control campaigns, based on individuals' years of birth and year surveyed. In a large majority of countries (14 of 22), we find that the program led to substantial increases in years of schooling and grade level as well as reductions in schooling delay. These countries are those for which pre-campaign educational resources are the highest. Moreover, although by and large positive, we find that the marginal returns of the Global Fund disbursements in terms of educational outcomes are decreasing. Our findings, which are robust to both the instrumentation of ecology and use of alternative ecology measures, have important policy implications on the value for money of malaria control efforts.

*Keywords*: Malaria, Sub-Saharan Africa, Education, Quasi-experimental

*JEL*: I15, I21, O19, O55

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# 1 Introduction

Malaria is a life-threatening disease. According to the World Health Organization, there were about 219 million cases of malaria in 2010 and an estimated 660,000 deaths. This disease is caused by protozoan parasites belonging to the genus *Plasmodium*. It is transmitted by several species of infected female anopheline mosquitoes.[1] Differences in the distribution of mosquitoes and in the behavior of potential human hosts contribute to the variation in epidemiological patterns of malaria seen worldwide. The majority of malaria-attributed deaths occur in Sub-Saharan Africa, where children under the age of five and pregnant women are the most at-risk.

Malaria does not only kill. It is also believed to impede human capital accumulation, and hence development, by generating school absenteeism and cognitive disorders (Jukes et al., 2009; Clarke et al., 2008; Bleakley, 2010; Lucas, 2010; Thuilliez et al., 2010; Venkataramani, 2012). The objective of this paper is to illuminate the impact of malaria on education. More precisely, we estimate the middle-run effects of early life exposure to the Global Fund to Fight AIDS, Tuberculosis and Malaria's anti-malaria campaigns on the educational achievements of primary school students across a wide range of African countries.[2]

Our empirical strategy relies on a quasi-experimental approach. This approach exploits geographic variation in pre-campaign malaria prevalence and variation in exogenous exposure to the timing and expenditure of anti-malaria campaigns, based on individuals' year of birth. More precisely, we combine educational data from the Demographic and Health Surveys (DHS) with measures of sub-national malaria ecology from the Malaria Atlas Project (MAP) as a proxy for pre-exposure malaria prevalence.

Other papers have also relied on a quasi-experimental approach. However, we improve upon this literature in three ways. First, the scope of our analysis (22 countries) is unprecedented. Second, contrary to the bulk of previous studies, we do not focus on the malaria periphery, i.e. the set of countries characterized by species of *Plasmodium* (*P. vivax*, *P. ovale* and *P. malariae*) that are the least harmful to human health. We concentrate instead

[1] Four species of these protozoan parasites account for almost all infections seen in humans: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale* and *Plasmodium malariae*. *Plasmodium falciparum* is the most aggressive of all and accounts for the majority of infections in Africa (Greenwood et al. 2005).

[2] "Middle-run effects" refer to the effects of a continued exposure to anti-malaria campaigns that varies between 0 and 10 years.

on countries where *P. falciparum*, the most aggressive of all species, is dominant. Third, we gauge the educational externalities of anti-malaria campaigns conducted by the current primary funder in the global health arena, the Global Fund. Indeed, a growing value for money agenda aims to reduce costs, increase impact per dollar spent, and focus investments on the highest impact interventions among the most affected populations. Education is not the primary goal of a malaria control campaign, but examining educational impacts of health programs adds to this literature by exploring if there is more education for the money invested by the Global Fund.

Meanwhile, we expect to illuminate how to improve the effectiveness of such campaigns in terms of educational outcomes. For instance, the impact of malaria control on educational achievements can be both positive and negative, depending on the availability of educational resources. Indeed, by reducing the mortality of children under the age of five, anti-malaria campaigns may impose considerable strain on those resources. Moreover, anti-malaria campaigns may potentially lead to a higher diversity among children enrolled, instead of enrollment being restricted only to those who survive to the disease. In the absence of sufficient educational resources, the weakest students who get enrolled thanks to the campaign will fall behind. Our analysis allows us to identify the countries where the impact of malaria control on educational achievement is negative, and why they emerge. Though tentative, this investigation should help improve understanding on the externalities of anti-malaria campaigns on education.

Our results reveal a positive impact of malaria control on educational attainment in a large majority of countries (14 of 22). The orders of magnitude for these countries are substantial. On average, a one-standard deviation increase in exposure to malaria control campaigns increases the total years of schooling completed as well as the grade level during the current school year by 0.6 standard deviations, and decreases delay status for current grade level by 1.2 standard deviations. Moreover, we find confirmation that this positive impact is correlated with pre-campaign GNI per capita (PPP), a proxy for the level of educational resources at a country's disposal.[3] Finally, although by and large positive, the

[3]We identify a second driver of anti-malaria campaigns' positive impact: the methodological adequacy of the data we use to run our quasi-experimental approach. Countries where the control group is not at all or hardly "treated" and where the exposure to anti-malaria control of the most treated group is high are more likely to exhibit a positive and significant impact of malaria control on educational attainment. This finding has methodological implications that we discuss in the paper.

marginal returns of the Global Fund disbursements in terms of educational outcomes are decreasing.

These findings have important implications for policy makers aiming to improve the externalities of anti-malaria campaigns on education. First, they suggest that these campaigns should be conducted alongside increases in educational resources. Second, in order to counterbalance these campaigns' diminishing marginal returns, one should not increase investment indefinitely. Instead, one should target, at each period of time, areas where the combined malaria reduction and improved education could be the highest (i.e. those where malaria prevalence is the highest and educational quality the lowest). Such an approach will ensure an optimal return on investment for each period of time. This is all the more true given that education can have long-term effects on health, which could generate a virtuous circle.

The paper proceeds as follows. In Section 2, we provide historical and biological evidence on the link between malaria and education. We present our empirical strategy in Section 3. In Section 4, we describe our data. Section 5 displays our results. Section 6 provides robustness checks. Finally, Section 7 summarizes our findings and their policy implications as well as highlights avenues for future research.

# 2 Malaria and education

There are a number of ways through which malaria can impact children's educational achievement. First, malaria during pregnancy can lead to foetal growth retardation which translates into cognitive and physical impairments among children. Barreca (2010) analyzes the long-term impact of *in utero* and postnatal exposure to malaria. He finds such exposure leads to considerably lower levels of educational attainment and higher rates of poverty later in life.

Second, during early childhood (under the age of five),[4] complicated forms of malaria may develop rapidly. The effects of severe malaria, better known as cerebral malaria, have been quantified by numerous studies (see Mung' Ala-Odera et al. (2004) for a literature review). For instance, Ngoungou et al. (2007) provide a quantification of the burden in West Africa. In this study, 101 subjects (mean age of 5.6 $\pm$ 3.6 years) who had had cerebral

[4]Acquired immunity in children does not play an efficient protective role until the age of 5 to 6, even in highly endemic areas, which highlights why malaria is a major threat to child survival.

malaria in Mali were followed from 1999 to 2001. The authors find that twenty-eight children exhibited persistent neurological sequelae (26.7 %). Among them, eight (7.9 %) children had developed these sequelae just after cerebral malaria and 20 (19.8 %) a few months later. These included headaches, mental retardation, speech delay, bucco-facial dyspraxia, diplegia and frontal syndrome (one case each), dystonia (two cases), epilepsy (five cases) and behaviours and attention disorders (15 cases).

Third, even during late childhood (which usually extends from 6 to 16 years of age), the protection conferred by acquired immunity is only partial. If cerebral malaria is rare at this stage, "'simpler"' cases of clinical malaria (called "uncomplicated malaria"), repeated illness, or chronic malaria infections are not. They can have a non-cognitive impact on educational achievement through school absenteeism, general health conditions, and investment in curative strategies (coping strategies against the disease detrimental to educational investments). For instance in a Kenyan case study, Brooker et al. (2000) attribute 13-50 % of medically related school absences to malaria. In Kenya, primary school students were determined to miss 11% of the school year (20 school days missed per child-year). In Nigeria, school days missed varied between 2% to 6% of the school year (3 to 12 days per year per student). In Mali, malaria was the primary cause of absenteeism during a full school year (Thuilliez et al., 2010). Moreover, although the age distribution of uncomplicated malaria and asymptomatic malaria depends on transmission intensity, the total burden of disease may be similar or even higher in settings of low transmission due to patterns of acquired immunity. Malaria morbidity among school-age children increases as transmission intensity decreases, but asymptomatic infections are more frequent in high transmission settings (Clarke et al., 2004; Dicko et al, 2007). Fernando et al. (2003) show a significant negative correlation between the total number of malarial attacks experienced by children and test scores during a six year follow-up. Fernando et al. (2006) and Jukes et al. (2009) also show a substantial effect of preventive treatment in two randomized studies. Yet, asymptomatic malaria has proven to have detrimental effects on children's cognitive and educational skills in three studies, one being a cluster-randomized control trial which suggests either a direct causal effect of the disease or an antimalarial treatment effect (Clarke et al., 2008; Thuilliez et al., 2010; Nankabirwa et al., 2013), although confirmatory studies are needed.

# 3 Empirical strategy

We aim to estimate the middle-run effects of early life exposure to the Global Fund anti-malaria campaigns on the educational attainment of primary school students across a wide range of African countries. In this section, we first describe our quasi-experimental approach and how it relates to previous studies. We then present the main features of anti-malaria campaigns in Africa. Finally, we discuss the key assumption that allows us to implement our empirical strategy: malaria ecology can be used as a proxy for pre-campaign malaria prevalence.

## 3.1 A quasi-experimental approach

We use Global Fund malaria control campaigns as quasi-experiments in Africa. This approach has been extensively applied to analyse the effect of malaria on socioeconomic factors. In a recent paper with a historical perspective, Bleakley (2010) considers the malaria eradication campaigns in the United States (1920) as well as Brazil, Colombia and Mexico (1950) in order to assess the impact of childhood exposure to malaria on labor productivity. Using a cohort-level dataset based on microeconomic data, Bleakley finds that cohorts born after eradication enjoyed higher levels of adult literacy than the preceding generation. The effect of childhood malaria exposure on adults is similar for all four countries in the study, while results were mixed for years of schooling. Lucas (2010) finds that malaria eradication increased female educational attainment (from between 0.39 and 0.93 years of schooling) and literacy (from between 2.5 and 7.8%) with a quasi-experimental procedure in Paraguay and Sri Lanka. In India, Cutler et al., (2010), using a similar quasi-experimental framework, find no evidence of increased educational attainment for men and mixed evidence for women. Lastly, Venkataramani (2012) finds a long-term increase in cognitive test scores in Mexico after the nationwide introduction of malaria eradication efforts in 1950. Cohorts born after eradication also entered and exited school earlier than their pre-eradication counterparts.

One limitation of these studies is that they use data from what Lucas (2010) terms the "malaria periphery," defined as areas in which malaria transmission was primarily seasonal or epidemic before eradication. These countries have particular epidemiological settings and, more specifically, were classified as *P. vivax*-dominant areas prior to eradication campaigns.

Thus, external validity is limited to these areas which are generally unaffected by the most severe *P. falciparum* malaria. Moving to the epicentre of severe malaria, Barofsky et al. (2011) use a natural experiment to investigate the outcome of a malaria eradication campaign in Kigezi, Uganda from the period of 1950 to 1960. They report that a decrease in malaria incidence of 10% produces an increase in educational attainment of 0.14 years or 3.6% for individuals between 20 and 40 years of age.

Similarly to previous studies, our experimental approach exploits geographic variation in pre-campaign malaria prevalence and variation in exogenous exposure to the timing and expenditure of anti-malaria campaigns, based on individuals' years of birth. More precisely, we combine educational data from the Demographic and Health Surveys (DHS) with measures of sub-national malaria ecology from the Malaria Atlas Project (MAP) as a proxy for pre-exposure malaria prevalence. This approach has the potential to be a good identification strategy providing that a number of conditions are satisfied.

First, malaria control should be the objective of the Global Fund malaria disbursements. In other words, the impact of the campaign should be more effective in regions with higher pre-campaign malaria prevalence. This argument is supported by Figure 1, which clearly shows a decreasing trend in the probability of malaria mortality in our 22 sample countries between 1980 and 2010. Declines are stronger for countries showing higher pre-campaign mortality. Furthermore, bednet rollout has also been related to improvements in health measures (Ashraf et al., 2010). In our sample, we observe a statistically significant increase in average household bednet usage for sleeping in general and for children under five after the campaign start years.

Second, the timing of the campaign must be exogenous, meaning that it is not concomitant with other programs aiming to improve educational outcomes in Africa. This is supported by the exogeneous discovery of ACTs as described in detail in the next sub-section as well as by the exogenous creation of the Global Fund, which was originally an answer to a more global public health threat, namely HIV/AIDS. Indeed, the Global Fund was founded in 2002 after a series of summits in 2000 and 2001. The first round of grants was approved shortly thereafter, only 3 months after the establishment of the permanent secretariat.[5] At

[5]Additional information on the timeline of the Global Fund can be found at its official website: http://www.theglobalfund.org/.

the beginning, a larger emphasis was placed on essential medicines for HIV, largely considered as a global public good, rather than malaria. Thus, the timing of funding disbursement was based on international consensus and trends in policy.

Finally, in order for us to be confident in our identification strategy, the Global Fund disbursements received by African countries should be orthogonal to their pre-campaign educational outcomes. Disbursements themselves rely heavily on donor funding, and education is not an explicit element of the funding eligibility criteria.[6] Moreover, educational outcomes are not correlated to disbursements in our data.[7]

## 3.2 Anti-malaria campaigns in Africa

The first "'eradication program"' was launched in Africa in the late 1940s to early 1950s. Overall, malaria-related deaths in Africa showed evidence of a relative decline from the 1950s to the 1980s. But afterwards, the downward trend in malaria mortality appears to have reversed due to chloroquine[8] resistance as well as the relatively limited impact of the insecticide DDT in Sub-Saharan Africa.[9]

In the late 90s, the Chinese drug artemisinin was hailed as one of the greatest advances in fighting malaria, since the discovery of quinine[10] centuries ago. This treatment was not new (Klayman, 1985), but the first artemisinin-based combination therapies (ACTs, Coartem) were provided by Novartis at reduced prices to the World Health Organisation in 2001. The emergence of ACTs can be seen as an exogenous event to the African context - it was made possible by innovations in knowledge and spending, as well as the political openness of China and the interests of private actors. Such shocks came from outside the studied areas, comparable to the 19th century discoveries made by Nobel Laureates Laveran and

[6]The technical criteria center primarily on high disease burdens while requirements on the functioning of coordinating mechanism suppose broad and inclusive membership, documented procedures for monitoring conflict of interest, and transparent processes.

[7]We check correlations between primary school outcomes in 2002 (the year before the Global Fund's start) and per capita Global Fund disbursement during start years for each country within our sample. Narrow measures of attainment such as repetition and schooling delay exhibit low correlations (0.15 and 0.04, respectively) that are not significant.

[8]Used for both malaria treatment and prevention, chloroquine is a derivative of 4-aminoquinoline which prevents the development of malaria parasites in the blood.

[9]In contrast, Asian malaria transmission was much more sensitive to vector control measures using DDT because of the lower transmission intensity and relative organizational and political stability after the second World War (Carter and Mendis, 2002).

[10]Lauded as the first successful method for treating malaria, quinine was later replaced by chloroquine due to the latter's milder side effects.

Ross.[11] Such shocks thus mitigate the concern of reverse causality in our study, whereby local increases in human capital might influence malaria prevalence. Approximately at the same time, in 1998, the World Health Organisation (WHO) launched a second campaign aiming to halve malaria deaths worldwide by 2010 (Nabarro and Tayler, 1998). The Global Fund to Fight AIDS, Tuberculosis and Malaria was created in 2002 and, soon after its founding, became the main multilateral funder in the global health arena. The Global Fund channels 82% of the international financing for tuberculosis, 50% for malaria, and 21% for AIDS.[12]

As reported in Table 1, most of GF anti-malaria campaigns started in 2003 or 2004 in the 22 countries that constitute our sample. These campaigns aim to reduce deaths and illness from the disease. This objective is achieved by limiting the transmission of the disease from mosquitoes to human beings as well as by treating most of the clinical cases. Notably, vector *(Anopheles* mosquitoes) elimination is not itself a goal. Complete eradication has indeed proven to be globally difficult, and new techniques such as genetically modified organisms (GMOs) or sterilization are still experimental. Hence, malaria control relies mainly on insecticide treated nets (ITNs), artemisinin-based combination therapy (ACT), and indoor residual spraying (IRS). These approaches are sometimes combined with larval control which eliminates mosquitoes at their larval stage. However, larval control is recommended only for specific settings due to its detrimental effects on the environment and poor cost-effectiveness. We describe the implications of these techniques for our identification strategy in the following section.

## 3.3 Malaria ecology as a proxy for pre-campaign malaria prevalence

We base our identification strategy on malaria ecology which is in line with previous quasi-experimental studies (Bleakley, 2010; Lucas, 2010; Venkataramani, 2012). Malaria ecology has been previously defined (Kiszewski et al., 2004) as an ecologically-based spatial index of the stability of malaria transmission. Malaria is moreover said to be stable if it is transmitted

[11] Bleakley (2010) describes these significant twin discoveries - that malaria is caused by a single-celled organism and transmitted by mosquitoes.

[12] The second and third largest funders are the President's Malaria Initiative and the World Bank Booster Program for Malaria Control in Africa.

throughout the year by long-lived, anthropophilic vector anopheline mosquitoes (Kiszewski et al., 2004). There are a number of reasons why malaria ecology is a good proxy for malaria prevalence before the start of anti-malaria campaigns.

First, the species of *Anopheles* present in an area at a given time will influence the intensity of malaria transmission. Of the approximately 462 known species of *Anopheles*, only 70 transmit malaria in nature (Hay et al., 2012). However, not all *Anopheles* are equally effective "vectors" for transmitting malaria from one person to another. Certain *Anopheles* species may differ in selected behavioral traits, with important consequences on their abilities as malaria vectors. Even so, the distribution of vectors depends primarily on environmental and climatic predictors. As a result, variation in vectorial capacity to transmit malaria is largely local, fluctuating according to the precipitation and temperature relevant to the ecology and bionomics of vector species (Bhattacharyya, 2009). Thus, all basic formulas for malaria ecology take climatic characteristics, the presence of different mosquito species, and the human biting rate of the different mosquito vectors into account.

Second, in areas where malaria has not been eliminated, malaria ecology is strongly correlated to malaria prevalence.[13] Hamoudi and Sachs (1999) note that malaria vectors remain even in countries that have eradicated malaria, indicating that the danger of resurgence persists (which explains why most European countries still take surveillance of malaria seriously). In other words, because it is built upon climatological and vector characteristics, malaria ecology is considered exogenous to public health interventions and economic conditions (Kiszewski et al., 2004).

Our malaria ecology measure is an average index of vector species presence which captures the distribution of mosquitoes at the DHS cluster level. We rely on the vector distribution map provided by the Malaria Atlas Project (MAP). To derive this ecology measure from vector species, we take the weighted average of the probability of occurrence for all *Anopheles* species present within a given cluster. Due to their proliferation, some vectors are considered dominant over others. We do not rely only on the dominant vectors for a given country but rather give equal weight to all species since our unit of observation - the DHS cluster - is highly localized. This strategy implies that different species must be taken into account for

[13] In our dataset, the correlation between malaria ecology and the probability of dying from malaria for all ages (provided by Murray et al., 2012) ranges from 0.29 in 2002 to 0.52 in 2010.

each country, described further in Section 4.2.

We note that our index diverges from that which has been recently used in the economic literature. Over the period of 1901 to 1990, Kiszewski et al. (2004) averaged monthly temperature and precipitation to generate a single cross-sectional value of malaria ecology. The authors published a global distribution map for the major malaria vectors, which was created to assist in the development of a malaria transmission maps. It has since been widely adopted for economic studies on malaria (see Gallup and Sachs, 2001; Cartensen and Gundlach, 2006; Bleakley, 2010; and Lucas, 2010 among others).

There are a number of reasons why we use an alternative measure to the Kiszewski et al. (2004) index. First, the vector distribution maps have a more precise resolution, 5 x 5 km resolution grids, (Sinka et al., 2006) which causes our index to have a greater degree of variation. Second, the data compiled by the MAP were collected from 1984 to 2009, rendering these maps a relatively smooth representation of vector distribution for our period of analysis (2003 to 2011). Even considering these differences, our index is highly correlated to the Kiszewski et al. (2004) index which we later use as substitute to check the robustness of our results.

For our identification strategy to be valid, malaria ecology must remain unaltered from anti-malaria campaigns and climate change during our period of analysis. Climate change hypotheses propose that increased temperature and precipitation facilitate the emergence and persistence of *Anopheles* mosquitoes (Harvell et al., 2009). This suggests that, within our relatively short period of time, *Anopheles* mosquitoes should have remained stable or increased in the absence of health interventions. Consequently, climate change is unlikely to present a problem for our identification strategy. Of more concern is the potential impact of malaria control interventions on the ecology of major malaria vectors from 2003 to 2011. Vector distributions before and after Global Fund programs have unfortunately not been documented extensively. Consequently, we rely on past and contemporaneous arguments to argue that this impact should be relatively low.

The first argument is linked to the nature and importance of vector management control actions as part of the malaria control toolkit. Vector control generally seeks to reduce malaria transmission but does not necessarily exert an influence on the direction of vector distribution. In recent years, vector control, based on insecticide-treated nets (ITNs), indoor

residual spraying (IRS), and larval control, is only one element of malaria control strategies. Tremendous progress had been made in the distribution of ITNs, especially in Africa, where it is estimated that more than half of all households in malaria-endemic areas had at least one ITN in 2012. Lengeler et al. (2004) identify and systematically review 22 ITN trials, 13 of which are from Sub-Saharan Africa. The broad evidence synthesized in this study concludes that there is a substantial effect of ITNs on reducing the burden of malaria.[14] Despite this progress, programs are still far from universal coverage targets. Moreover, even if net usage is sustained at high levels, the biting behaviors of vectors may change and thus maintain high malaria prevalence (Moiroux et al., 2012).

The proportion of the population protected by IRS also increased substantially in the African region from 2006 to 2008, and the increased coverage was maintained above 10 % from 2009 to 2011. However, this figure still remained relatively low in 2011: 77 million people in the region, or 11 % of the population at risk, were estimated to be protected. In countries employing both ITNs and IRS, the extent to which the populations targeted for these interventions overlap is difficult to quantify, but it is likely to be small. Only 9 countries in Africa use larval source management strategies (WHO, 2012). IRS, mainly with DDT, was the principal method by which malaria was eradicated or greatly reduced in many countries in the world between the 1940s and 1960s. In Sub-Saharan Africa, as already mentioned, the success of DDT campaigns was limited. Early malarial eradication pilot projects showed that malaria is highly responsive to vector control by IRS but that transmission could not be interrupted in the endemic tropical and lowland areas (Mabasco et al., 2004). Zhou et al. (2013) showed recently that integrated vector control measures had modest additive effects on transmission in western Kenya and that IRS had a modest impact on reducing vector density in 2011. Thus, vector control methods have been shown to be successful at reducing malaria transmission, but they do not impact the distribution of vectors themselves.

The second argument for the exogeneity of our malaria ecology measure relates to *Anopheles* resistance to insecticides. The proliferation of insecticide resistance as a major threat to vector control programs has been widely documented (Santolamazza et al., 2008). For

[14] Of course, these RCTs are conducted under perfect experimental conditions with high levels of education which masks the variation likely to be seen in more expansive samples.

example, if mosquitoes are resistant to the insecticide(s) used locally for spraying or treating bed nets, these measures will be ineffective at curbing transmission. All WHO-recommended ITNs and LLINs use pyrethroids.[15] As malaria vector control, and consequently the success of global malaria control, is heavily reliant on this single class of insecticide, an increasing resistance of malaria vectors to pyrethroids and to other insecticides jeopardizes global malaria control efforts. Mosquito resistance to at least one insecticide used for malaria control has been identified in 64 countries, pyrethroid resistance being particularly problematic in Africa. Though this issue has long been acknowledged, countermeasures have been recent. In 2011, the World Health Assembly and the Board of the Roll Back Malaria Partnership requested the WHO to draft a global strategy to provide a basis for coordinated action to maintain the effectiveness of vector control interventions. However, the Global Plan for Insecticide Resistance Management in malaria vectors was launched in May 2012, which is much too recent to have an impact during our period of analysis.

# 4 Data

## 4.1 Educational attainment

We use household member information from Demographic and Health Surveys (DHS) to develop our measures educational attainment. Specifically, we focus on those individuals currently enrolled in primary school.[16] Among these children, we study three types of educational outcomes: total years of schooling completed, grade level during the current school year, and delay status for current grade level. At first glance, years of schooling and grade level might seem as though they capture the same information, yet due to delay and repetition the current grade of a student does not necessarily reflect the number of years in school. A student is considered delayed if they are above-age for their grade level. To capture this status, we employ a dummy variable equal to one if a student's observed grade level is lower than their predicted grade level within each country.[17]

[15] Currently, insecticides used for IRS come from four classes: pyrethroids (the most common), organochlorines (of which DDT is the only compound in use), organophosphates, and carbamates.

[16] Primary school enrollment has been increasing steadily over time, whereas other educational indicators exhibit much less stable trends.

[17] We follow the procedure of Mock and Leslie, 1986.

Summary statistics for each dependent variable by country can be found in Table 2. Additionally, Table 2 shows that the number of primary school students within our sample varies greatly by country, depending upon the number of DHS rounds included simultaneously. The sample size ranges from as low as 5,384 students in Liberia to as many as 69,898 in Malawi. Average ages for primary school students span from 9.37 years old in Madagascar to 12.85 in Liberia.

In addition to educational measures, we also draw controls on the gender, age, and wealth[18] of enrolled students from the DHS.

## 4.2 Malaria ecology

As described in Section 3.3, we derive our malaria ecology measure from the distribution of species vectors. To do so, we use the weighted average of the probability of occurrence for all mosquito species present within a given cluster. Because our unit of measurement is at the DHS cluster level, we use both dominant and secondary vectors to compute our ecology index. Indeed, focusing only on the dominant vectors in a particular setting would potentially reduce the variation in our ecology measure by ignoring secondary vectors in localized areas. This approach to computing the ecology measure implies that different species must be taken into account for each country: Burkina Faso, Malawi, Mali, Namibia (funestus, nili, gambiae, arabiensis); Burundi, Rwanda, Uganda, Zambia (funestus, nili, gambiae, arabiensis, moucheti); Cameroon, DRC, Nigeria (funestus, nili, gambiae, arabiensis, melas, moucheti); Ethiopia (funestus, nili, arabiensis); Ghana, Guinea, Liberia, Senegal, Sierra Leone (funestus, nili, gambiae, arabiensis, melas); Kenya, Tanzania (funestus, nili, gambiae, arabiensis, moucheti, merus); Madagascar (funestus, gambiae, arabiensis, merus); Mozambique, Zimbabwe (funestus, nili, gambiae, arabiensis, merus). We report the summary statistics for malaria ecology in Table 2.

## 4.3 Exposure to malaria control campaigns

We define exposure as the percentage of a child's life during which he or she is exposed to the Global Fund campaign multiplied by the average yearly amount per capita[19] (USD)

[18] Wealth is an asset-based index ranging from one (poorest) to five (richest).

[19] Yearly population data come from the World Development Indicators.

disbursed by the Global Fund during this time period of exposure.[20] Exposure averages for all clusters within a given country can be found in Table 2.

For example, an Ethiopian child surveyed in 2000 would experience no exposure at all since the Global Fund disbursements were to begin only in 2003. In contrast, a child surveyed in 2010 would experience at least seven years of exposure out of their lifetime, unless he or she was born after 2003. Thus, the exposure measure for a child surveyed in 2010 and born before 2003 would equal the percentage of their lifetime exposed to the campaign multiplied by the average of disbursement per capita during the time period from 2003 to 2010. The exposure measure for a child surveyed in 2010 but born in 2004, for instance, would account for only six years of exposure instead of seven due to the later date of birth. For this child, exposure will equal the percentage of their lifetime exposed to the campaign multiplied by the average of disbursement per capita during the shorter time period of 2004 to 2010.

# 5 Results

In this section, we first present our specification. We then present and discuss our estimates.

## 5.1 Specification

Our quasi-experimental approach relies on the following equation:

$$\begin{aligned} educ_{icjt} = \quad & a + b.(malaria_j \times exposure_{ct}) + c.(malaria_j \times age_{ct}) + d.(\delta_r \times exposure_{ct}) \\ & + e.(\delta_r \times \delta_c) + \mathbf{X_{icjt}}'.\mathbf{\Gamma} + \delta_c + \delta_j + \delta_t + \epsilon_{icjt} \end{aligned}$$

In this equation, subscript $i$ refers to individual $i$, subscript $c$ to cohort $c$ (a group of individuals born in year $c$), subscript $j$ to DHS cluster $j$ and subscript $t$ to DHS survey year $t$. The dependent variable $educ_{icjt}$ describes the educational attainment (total years of schooling completed, grade level during the current school year, or delay status for current grade level) of individual $i$ from cohort $c$ who lives in cluster $j$ at DHS survey year $t$. Variable $malaria_j$ is the pre-campaign malaria prevalence (i.e. malaria ecology) in cluster $j$. Variable

[20] More precisely, we multiply the percentage of lifetime exposed with the average yearly amount per capita during this time period of exposure. Ultimately, this amounts to the fraction of total amount per capita (USD) disbursed by the Global Fund during this time period of exposure over a child's complete lifetime.

$exposure_{ct}$ captures the exposure to malaria control campaigns. As emphasized in subsection 4.2, this exposure ultimately boils down to computing the total amount per capita (USD) disbursed by the GF during a child's lifetime, normalized by this child's lifetime. Since a child's lifetime depends both on his or her year of birth and on the year when the DHS survey is conducted, $exposure_{ct}$ varies across cohorts as well as DHS survey years. The interaction term between $malaria_j$ and $exposure_{ct}$ is the main variable of interest in our empirical strategy. It allows us to exploit geographic variation in pre-campaign malaria prevalence at the cluster level and variation in exogenous exposure to the timing and expenditure of anti-malaria campaigns, based on individuals' birth and survey years. As a consequence, coefficient $b$ captures the impact of malaria control on educational attainment.

To be sure, educational attainment can be influenced by characteristics at the individual, cohort, cluster, and DHS survey year levels. We therefore control in our specification for a vector of individual socio-economic characteristics denoted by $\mathbf{X_{icjt}}$. This vector contains information on the gender, age and wealth of individual $i$. Moreover, we control for cohort, cluster and DHS survey year fixed effects denoted by $\delta_c$, $\delta_j$ and $\delta_t$ respectively.

Despite these controls, one may worry that the interaction term between $malaria_j$ and $exposure_{ct}$ is correlated to a number of omitted variables that could generate a biased estimate for coefficient $b$. First, by definition, an individual's exposure to malaria control campaigns negatively depends on his or her age (i.e. the difference between DHS survey year and the individual's date of birth). Therefore, coefficient $b$ potentially captures how the impact of malaria prevalence on educational attainment varies across age. To avoid this bias, we control in our specification for the interaction term between $malaria_j$ and $age_{ct}$. Second, a higher pre-campaign prevalence at the cluster level is likely correlated with poorer pre-campaign educational outcomes at this level. As a result, coefficient $b$ may capture how the impact of malaria control campaigns varies, depending on pre-campaign educational attainment. To rule out this possibility, we obviously cannot control for the interaction term between cluster fixed effects and exposure to malaria control campaigns since this would drop the main variable of interest in our analysis, i.e. $(malaria_j \times exposure_{ct})$. Instead, we control for $(\delta_r \times exposure_{ct})$ which is the interaction term between regional fixed effects and exposure. Third, as emphasized in Section 3.2, evidence suggests that the timing and disbursements of the Global Fund anti-malaria campaigns are orthogonal to trends in ed-

ucational attainments. We nevertheless seek to control for such trends (and notably for those which are region- and cohort- specific) by including in our specification ($\delta_r \times \delta_c$), an interaction term between region and cohort fixed effects.

## 5.2 Estimates

OLS estimates of coefficient $b$ are reported in Table 3. More precisely, Table 3 displays the impact of malaria control on total years of schooling completed (columns 1 through 4), on grade level during the current school year (columns 5 through 8) and on delay status for current grade level (columns 9 through 12). Controls are entered stepwise. In columns 1, 5 and 9, we control for individual gender, age, wealth, as well as for cohort, cluster and DHS survey year fixed effects. We then add the interaction term between pre-campaign malaria prevalence and age (columns 2, 6 and 10), the interaction term between regional fixed effects and exposure to malaria control campaign (columns 3, 7 and 11), and finally the interaction term between region and cohort fixed effects (columns 4, 8 and 12).

Three groups of countries emerge. A first group ("Group 1" hereafter) refers to countries where the impact of malaria control is weakly positive (i.e. strictly positive or null). It includes countries where the impact of malaria control on educational attainments is positive and significant for at least one of our three dependent variables (the impact for the other dependent variables being non-significant). A second group ("Group 2" hereafter) refers to countries where the impact of malaria control is null. It concerns countries where the impact of malaria control on educational attainments is significant for none of our three dependent variables. A third group ("Group 3" hereafter) refers to countries where the impact of malaria control is weakly negative (i.e. strictly negative or null). It includes countries where the impact of malaria control on educational attainment is negative and significant for at least one of our three dependent variables (the impact for the other dependent variables being non-significant). Figure 2 helps us to visualize these three groups of countries.

The large majority of countries (14 of 22) show a weakly positive impact of malaria control on educational attainment. The orders of magnitude are reported in Figure 3. These orders of magnitude are substantial for Group 1. On average, a one-standard deviation increase in exposure to malaria control campaigns increases the total years of schooling completed as well as the grade level during the current school year by 0.6 standard deviations, and

decreases delay status for current grade level by 1.2 standard deviations.

## 5.3 Discussion

Our objective in this paper is not only to estimate the middle-run effects of early life exposure to the Global Fund's anti-malaria campaigns on the educational achievements of primary school students. We also aim to illuminate how the effectiveness of such campaigns can be improved in terms of educational outcomes.

A first step toward improving the effectiveness of anti-malaria campaigns is to understand why the impact of malaria control on educational achievement is not (weakly) positive in all 22 countries. A first explanation is related to the availability of educational resources. Indeed, by reducing the mortality of children under the age of five, anti-malaria campaigns may impose considerable strain on these resources. Moreover, anti-malaria campaigns may potentially lead to a higher diversity among children enrolled, instead of enrollment being restricted only to those who survive to the disease. In the absence of sufficient educational resources, the weakest students who are enrolled thanks to the campaign will likely fall behind. One therefore expects that the probability for a country to belong to Group 1 (rather than to Group 2 and Group 3) is correlated with the level of educational resources at its disposal. A second explanation for why not all 22 countries belong to Group 1 is methodological. For the impact of anti-malaria control to be positive and significant for at least one of our three dependent variables, one obviously needs (i) a control group which is hardly or not at all "treated" (i.e. exposed to anti-malaria control), and (ii) a substantial difference in exposure to anti-malaria control between the most treated group and the control group.

This intuition is supported by evidence. We rely on pre-campaign GNI per capita (PPP) as a proxy for the level of educational resources at a country's disposal. We find a positive and significant correlation (at the 95% confidence level) between the probability for a country to belong to Group 1 and its pre-campaign GNI per capita. Moreover, we create a "methodological adequacy" variable. This variable captures (i) whether at least one DHS survey was conducted in a specific country before the start of the anti-malaria campaign or the year when this campaign was launched and (ii) the maximal value of the exposure variable in this country. When the first dimension is satisfied, this ensures that the control

group is composed of individuals who were not exposed or hardly exposed (only 1 year) to the anti-malaria campaign. As for the second dimension, the greater the maximal value of the exposure variable in a specific country, the higher the difference in exposure between the most treated group and the control group. Our results show a strongly positive and significant correlation (at the 99% confidence level) between the probability for a country to belong to group 1 and its "methodological adequacy". Hence, outliers (countries from Group 2 and Group 3) can be accounted for by both resource-related and methodological reasons. This finding has two implications. First, it invites policy makers to accompany anti-malaria campaigns with increases in educational resources. Second, it encourages researchers to rely on quasi-experimental data that offer enough room for a treatment effect.

A second step toward improving the effectiveness of malaria control campaigns is to analyze the marginal returns of the Global Fund disbursements in terms of educational outcomes. Figure 3 indicates these marginal returns are (mainly) positive but also decreasing. Put differently, we do find that there is more education for the money invested by the Global Fund but that the absolute value of this effect is marginally decreasing with increasing resources invested. This is an important conclusion with policy implications. Indeed, a consequence of diminishing marginal returns is that as total investment increases, the total return on investment as a proportion of the total investment (the average return) decreases. Consequently, the long-term solution to this problem is not to increase investment indefinitely, but to target, at each period of time, areas where the combined malaria reduction and improved education could be the highest (i.e. those where malaria prevalence is the highest and educational quality the lowest). Such an approach will ensure an optimal return on investment at each period of time. This is all the more true that education can have long-term effects on health, which could generate a virtuous circle.

Let us conclude by emphasizing that Figure 3 shows a consistent trend for all educational outcomes used in this study. This is a strong argument in favor of the robustness of our evaluation of a public-private partnership such as the Global Fund campaigns.

# 6 Robustness

Our quasi-experimental approach relies on the exogeneity of variation in both malaria ecology and exposure to Global Fund campaigns. To verify the validity of our results, we examine both of these measures carefully.

Measures of malaria severity prior to control campaigns are often crude, such that it is difficult to quantify how areas with high infection rates benefited relative to areas with lower infection rates. Our vector-based measure of malaria ecology should capture this pre-campaign malaria severity but, if it does not do so accurately, we may face bias in our results. We therefore pursue three additional specifications to verify the validity of our ecology measure: We first follow Bleakley (2010) who uses 2SLS estimates to correct for measurement error in ecology. We instrument our malaria ecology measure with two factors known to influence malaria infection but not educational outcomes: inherited G6PD deficiency and malaria's basic reproductive number under control. We then substitute our preferred ecology measure with two alternative vector-based measures, the entomological inoculation rate which captures the intensity of malaria transmission, and a stability index developed by Kiszewski et al. (2004).

It is possible that exposure to Global Fund disbursements is highly correlated with exposure to other anti-malaria campaigns. The second and third largest malaria control campaigns to date are the President's Malaria Initiative and the World Bank Booster Program for Malaria Control in Africa. However, since our quasi-experimental strategy relies on differential exposure across time to produce a distinctive counterfactual, both of these programs prove difficult to test since their starting dates fall relatively late in our DHS survey time periods. For example, PMI disbursements began in 2006 for two of our sample countries (Tanzania and Uganda) and 2007 for an additional four countries (Malawi, Mozambique, Rwanda, and Senegal), with the remaining countries following in 2008 and later. World Bank Booster Program disbursements began in 2005 for two of our sample countries (DRC and Zambia) with the remaining disbursements beginning in 2006 (Burkina Faso, Ethiopia, Malawi, Nigeria, and Senegal) and 2007 (Ghana, Kenya, and Tanzania). Due to this lack of overlap with our DHS survey years, we are therefore unable to apply our quasi-experimental strategy.

## 6.1 Instrumental variables approach

We rely on two variables to instrument our vector-based malaria ecology variable: inherited G6PD deficiency and the basic reproductive number under control.

Several innate factors, naturally distributed characteristics of a host, influence malaria infection. For example, individuals who carry the sickle cell trait (heterozygotes for the abnormal hemoglobin gene HbS) will be relatively protected against severe disease and death caused by *P. falciparum* malaria. The prevalence of hemoglobin-related disorders and other blood cell dyscrasias, such as Hemoglobin C, the thalassemias and G6PD deficiency, are thought to provide protection from malaria and, moreover, are more prevalent in malaria endemic areas.

Two inherited blood disorder variables are available in the MAP database: the frequency of G6PD deficiency and the abnormal hemoglobin gene HbS. To our knowledge, G6PD deficiency has not been associated with poor educational or cognitive outcomes in the literature (Olson et al., 2009) whereas the sickle cell trait has been associated with Central Nervous System-related complications (Armstrong et al., 1996). We therefore rely on G6PD deficiency as an instrument for malaria ecology.

In addition to this inherited blood disorder, we use the *P. falciparum* basic reproductive number under control (PfRc) calculated with a modified version of Macdonald's formula, which takes into account a population where there is some level of control that lowers vector capacity. The PfRc indicates the basic reproductive number under control within the range of stable *P. falciparum* transmission and shows the potential for malaria to spread within a naïve population moderated by malaria control (Smith et al., 2007; Gething et al., 2011). It is indeed highly improbable for households to know the value of PfRc, which is a theoretical epidemiological notion (Seban et al., 2013). Therefore, there is no reason to believe that the PfRc is a cause of poor educational outcomes apart from the direct influence of malaria infection on education.

Table 4 presents 2SLS estimates for each dependent variable by country. To create our instruments, we separately interact G6PD deficiency and the basic reproductive number under control with exposure to the Gloal Fund campaign. We then use these variables to simultaneously instrument the interaction between malaria ecology and exposure to the Global Fund campaign. First-stage results (available upon request) confirm that our in-

struments are strong and refute overidentification. The results confirm the positive impact of exposure to Global Fund campaigns on schooling attainment and grade level, as well as the negative impact on delay. Results remain strongly significant for 11 countries (Burkina Faso, Cameroon, Ethiopia, Ghana, Malawi, Mali, Namibia, Nigeria, Rwanda, Uganda, and Zimbabwe).

### 6.2 Two alternative malaria ecology variables

Tables 5 and 6 present OLS results with alternative variables for malaria ecology. In Table 5, we first substitute the entomological inoculation rate (EIR). The EIR is estimated from the human biting rate of mosquitoes and the fraction of infectious vectors (Kelly-Hope and McKenzie, 2009). It is therefore a natural substitute to our original vector-based ecology measure. Table 6 introduces the Kiszewski et al. (2004) index which relies on averaged monthly temperature and precipitation.[21] As before, our original results are robust to these alternative ecology measures.

## 7 Conclusion

Malaria impacts not just mortality - it also produces nuanced outcomes related to health and education. The early 21st century has seen renewed efforts toward fighting this disease. Various funders have undertaken malaria control efforts in Sub-Saharan Africa, with the Global Fund emerging as a leader in terms of both duration and disbursements. While control efforts have seen substantial decreases in malaria prevalence, the effects on secondary outcomes such as education are less clear. With this paper, we seek a better understanding of the impact of malaria control efforts on educational outcomes among primary school students.

Using a quasi-experimental approach that relies on geographic variation in pre-campaign malaria prevalence and variation in exogenous exposure to the timing and expenditure of anti-malaria campaigns, we study the middle-run impacts of the Global Fund's malaria control campaigns. We find that, in 14 of 22 countries, exposure to malaria control campaigns yields positive impacts on educational outcomes. More precisely we observe that, on average,

[21] We note that this index is closely correlated to our own.

a one standard deviation increase in exposure to malaria control campaigns increases the total years of schooling completed as well as the grade level during the current school year by 0.6 standard deviation, and decreases delay status for current grade level by 1.2 standard deviation. For the remaining countries, which exhibit either no impact or a negative impact of exposure on educational outcomes, we find that these results seem to be driven education-related resource constraints as well as methodological limitations to our quasi-experimental approach.

With colossal amounts of funding on the table, researchers have begun to push the Global Fund for "more health for the money."[22] We strive to place our results in this context. Although we do find that there is more education for the money invested by the Global Fund, the absolute value of this effect is marginally decreasing with increasing disbursements. Such a relationship implies that disbursements should be targeted to areas which stand to see the most gain - those in which malaria prevalence is highest and educational quality is lowest. Continuing efforts to examine the value for money of such massive health investments as well as the precise channels through which malaria control campaigns can impact educational outcomes constitute important avenues for further research.

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# 8 Figures & tables

**Figure 1**: Probability of dying from malaria for children under five (1980-2010)

*Data source: Institute for Health Metrics and Evaluation from Murray et al. (2012)*

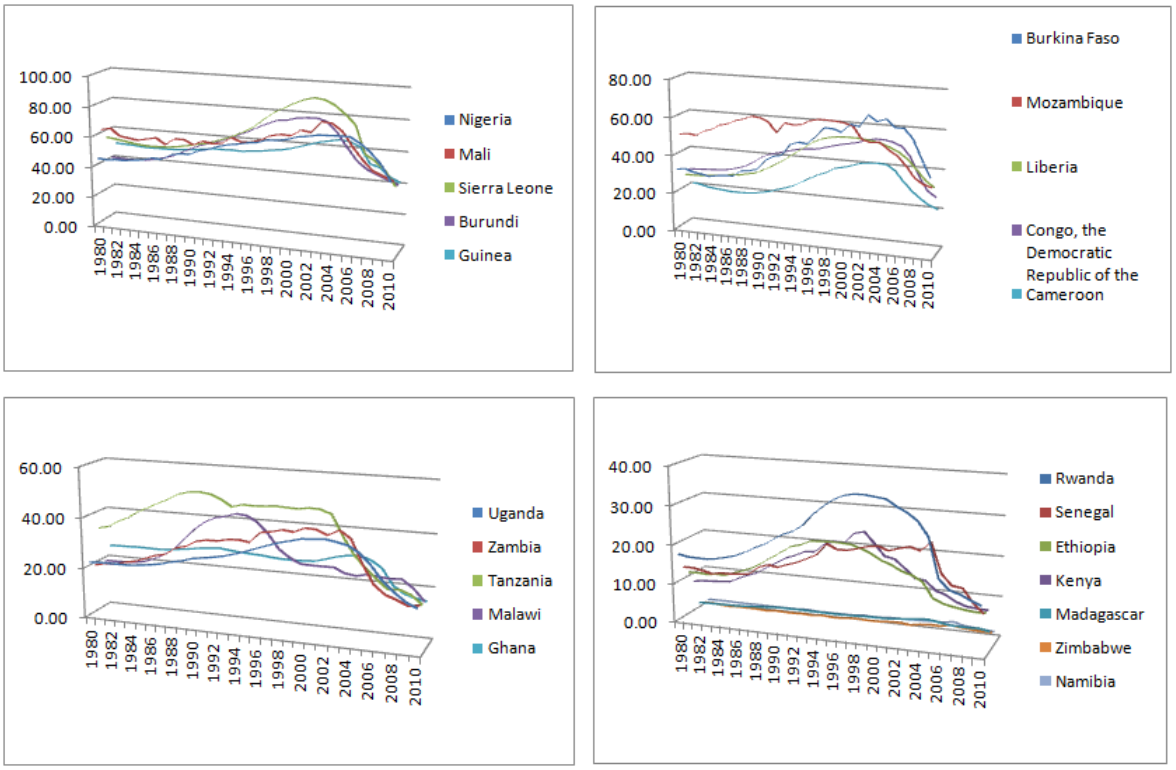

**Figure 2**: Summary of expected impact of Global Fund exposure on educational outcomes

| Country | Year | Grade | Delay |
|---|---|---|---|
| Burkina Faso | + | + | + |
| Burundi | + | + | + |
| Cameroon | + | + | + |
| DRC | - | - | - |
| Ethiopia | + | + | + |
| Ghana | + | + | + |
| Guinea | - | - | - |
| Kenya | + | + | + |
| Liberia | - | - | + |
| Madagascar | - | - | - |
| Malawi | + | + | + |
| Mali | + | + | + |
| Mozambique | + | + | + |
| Namibia | + | + | + |
| Nigeria | + | + | + |
| Rwanda | + | + | + |
| Senegal | - | - | - |
| Sierra Leone | - | - | - |
| Tanzania | + | + | + |
| Uganda | - | - | + |
| Zambia | - | - | - |
| Zimbabwe | + | + | + |

*Notes*: This figure summarizes the results of our preferred quasi-experimental specification. Plus and minus signs indicate whether the direction of the effect of exposure to Global Fund campaigns on dependent variables years of schooling, current grade level, and delay status is expected or unexpected, respectively. Gray areas indicate a significant effect while white areas indicate the absence of a significant effect.

**Figure 3**: Fitted values plotted across Global Fund disbursement

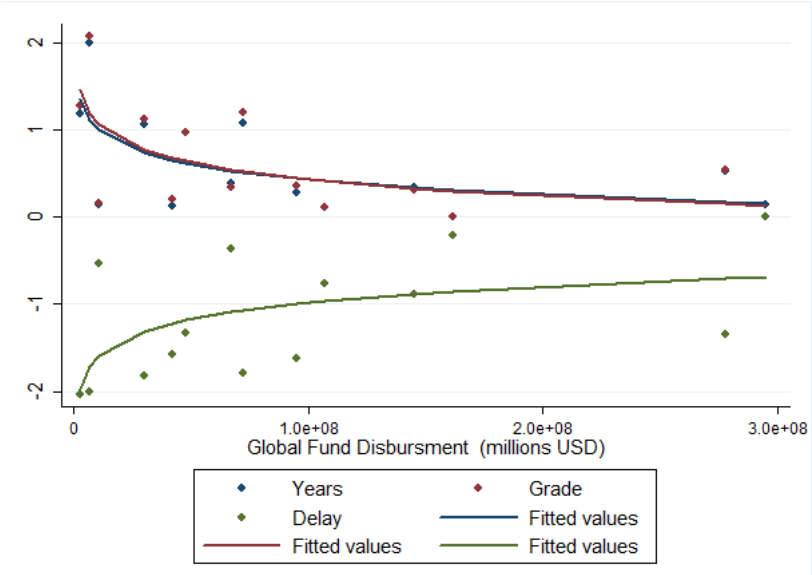

**Table 1**: Range of DHS year of birth cohort exposure to Global Fund campaigns

| | GF start date | DHS rounds available | Years of exposure |
|---|---|---|---|
| | (1) | (2) | (3) |
| Burkina Faso | 2003 | 2003; 2010 | 1-7 |
| Burundi | 2003 | 2010-11 | 7-8 |
| Cameroon | 2004 | 2004; 2011 | 1-7 |
| DRC | 2004 | 2007 | 3 |
| Ethiopia | 2003 | 2000; 2005; 2010 | 0-7 |
| Ghana | 2003 | 2003; 2008 | 1-5 |
| Guinea | 2003 | 2005 | 2 |
| Kenya | 2003 | 2003; 2008-9 | 1-6 |
| Liberia | 2004 | 2006-7 | 2-3 |
| Madagascar | 2003 | 2008-9 | 5-6 |
| Malawi | 2006 | 2000; 2004; 2010 | 0-4 |
| Mali | 2003 | 2001; 2006 | 0-3 |
| Mozambique | 2004 | 2011 | 7 |
| Namibia | 2004 | 2000; 2006-7 | 0-3 |
| Nigeria | 2004 | 2003; 2008 | 0-4 |
| Rwanda | 2004 | 2005; 2010-11 | 1-7 |
| Senegal | 2003 | 2005; 2010-11 | 2-8 |
| Sierra Leone | 2005 | 2008 | 3 |
| Tanzania | 2003 | 2009-10; 2011-12 | 1-9 |
| Uganda | 2004 | 2000-1; 2006; 2011 | 0-7 |
| Zambia | 2003 | 2007 | 4 |
| Zimbabwe | 2003 | 1999; 2005-6; 2010-11 | 0-8 |

**Table 2**: Descriptive statistics

| | | Mean | SD | Observations |
|---|---|---|---|---|
| | | (1) | (2) | (3) |
| Burkina Faso | Years | 2.82 | 1.75 | 16177.00 |
| | Grade | 3.31 | 1.69 | 16178.00 |
| | Delay | 0.37 | 0.48 | 16178.00 |
| | Age | 10.20 | 2.61 | 16180.00 |
| | Exposure | 0.04 | 0.02 | 16180.00 |
| | Malaria Ecology | 0.89 | 0.19 | 939.00 |
| Burundi | Years | 3.00 | 1.70 | 9113.00 |
| | Grade | 3.11 | 1.67 | 9110.00 |
| | Delay | 0.42 | 0.49 | 9110.00 |
| | Age | 11.87 | 3.23 | 9113.00 |
| | Exposure | 0.57 | 0.15 | 9113.00 |
| | Malaria Ecology | 0.68 | 0.10 | 381.00 |
| Cameroon | Years | 2.33 | 1.76 | 26681.00 |
| | Grade | 3.27 | 1.85 | 26683.00 |
| | Delay | 0.39 | 0.49 | 26683.00 |
| | Age | 9.54 | 3.12 | 26685.00 |
| | Exposure | 0.10 | 0.08 | 26685.00 |
| | Malaria Ecology | 0.70 | 0.12 | 1036.00 |
| DRC | Years | 2.19 | 1.66 | 8838.00 |
| | Grade | 3.13 | 1.66 | 8849.00 |
| | Delay | 0.41 | 0.49 | 8849.00 |
| | Age | 10.75 | 3.20 | 8849.00 |
| | Exposure | 0.06 | 0.02 | 8849.00 |
| | Malaria Ecology | 0.60 | 0.14 | 299.00 |
| Ethiopia | Years | 2.35 | 2.01 | 33548.00 |
| | Grade | 3.28 | 2.00 | 33546.00 |
| | Delay | 0.43 | 0.50 | 33546.00 |
| | Age | 11.98 | 3.72 | 33553.00 |
| | Exposure | 0.17 | 0.16 | 33553.00 |
| | Malaria Ecology | 0.74 | 0.22 | 1615.00 |
| Ghana | Years | 2.32 | 1.68 | 13043.00 |
| | Grade | 3.27 | 1.67 | 13043.00 |
| | Delay | 0.39 | 0.49 | 13043.00 |
| | Age | 10.21 | 2.87 | 13044.00 |
| | Exposure | 0.15 | 0.12 | 13044.00 |
| | Malaria Ecology | 0.79 | 0.18 | 814.00 |
| Guinea | Years | 2.22 | 1.69 | 5667.00 |
| | Grade | 3.20 | 1.68 | 5667.00 |
| | Delay | 0.41 | 0.49 | 5667.00 |
| | Age | 10.67 | 2.93 | 5667.00 |
| | Exposure | 0.05 | 0.02 | 5667.00 |
| | Malaria Ecology | 0.72 | 0.16 | 290.00 |

| | | | | |
|---|---|---|---|---|
| Kenya | Years | 3.48 | 2.34 | 18669.00 |
| | Grade | 4.13 | 2.39 | 18672.00 |
| | Delay | 0.30 | 0.46 | 18672.00 |
| | Age | 11.41 | 3.39 | 18672.00 |
| | Exposure | 0.13 | 0.13 | 18672.00 |
| | Malaria Ecology | 0.49 | 0.18 | 793.00 |
| Liberia | Years | 2.09 | 1.72 | 5384.00 |
| | Grade | 3.09 | 2.14 | 5380.00 |
| | Delay | 0.44 | 0.50 | 5380.00 |
| | Age | 12.85 | 3.67 | 5384.00 |
| | Exposure | 0.32 | 0.10 | 5384.00 |
| | Malaria Ecology | 0.76 | 0.11 | 186.00 |
| Madagascar | Years | 1.63 | 1.36 | 17268.00 |
| | Grade | 2.64 | 1.71 | 17275.00 |
| | Delay | 0.51 | 0.50 | 17275.00 |
| | Age | 9.37 | 2.65 | 17275.00 |
| | Exposure | 0.44 | 0.11 | 17275.00 |
| | Malaria Ecology | 0.72 | 0.17 | 594.00 |
| Malawi | Years | 2.77 | 2.17 | 69887.00 |
| | Grade | 3.41 | 2.15 | 69895.00 |
| | Delay | 0.42 | 0.49 | 69895.00 |
| | Age | 10.80 | 3.49 | 69898.00 |
| | Exposure | 0.18 | 0.18 | 65673.00 |
| | Malaria Ecology | 0.86 | 0.15 | 1942.00 |
| Mali | Years | 2.31 | 1.70 | 14718.00 |
| | Grade | 3.24 | 1.67 | 14726.00 |
| | Delay | 0.38 | 0.49 | 14726.00 |
| | Age | 10.16 | 2.77 | 14729.00 |
| | Exposure | 0.01 | 0.01 | 14729.00 |
| | Malaria Ecology | 0.79 | 0.28 | 741.00 |
| Mozambique | Years | 2.51 | 2.00 | 14100.00 |
| | Grade | 3.50 | 1.98 | 14099.00 |
| | Delay | 0.39 | 0.49 | 14099.00 |
| | Age | 10.35 | 3.15 | 14101.00 |
| | Exposure | 0.30 | 0.07 | 14101.00 |
| | Malaria Ecology | 0.77 | 0.14 | 609.00 |
| Namibia | Years | 3.03 | 2.00 | 14985.00 |
| | Grade | 3.90 | 1.98 | 14992.00 |
| | Delay | 0.30 | 0.46 | 14992.00 |
| | Age | 10.58 | 2.93 | 14995.00 |
| | Exposure | 0.24 | 0.25 | 14995.00 |
| | Malaria Ecology | 0.31 | 0.22 | 731.00 |
| Nigeria | Years | 2.37 | 1.71 | 28889.00 |
| | Grade | 3.23 | 1.84 | 28897.00 |
| | Delay | 0.40 | 0.49 | 28897.00 |
| | Age | 9.66 | 2.96 | 28898.00 |

| | | | | |
|---|---|---|---|---|
| | Exposure | 0.05 | 0.03 | 28898.00 |
| | Malaria Ecology | 0.70 | 0.14 | 1201.00 |
| Rwanda | Years | 2.15 | 1.70 | 24887.00 |
| | Grade | 2.78 | 1.62 | 24921.00 |
| | Delay | 0.50 | 0.50 | 24921.00 |
| | Age | 11.17 | 3.16 | 24922.00 |
| | Exposure | 0.77 | 0.63 | 24922.00 |
| | Malaria Ecology | 0.59 | 0.13 | 967.00 |
| Senegal | Years | 2.30 | 1.72 | 20978.00 |
| | Grade | 3.27 | 2.52 | 20991.00 |
| | Delay | 0.40 | 0.49 | 20991.00 |
| | Age | 10.17 | 2.91 | 20992.00 |
| | Exposure | 0.18 | 0.07 | 20992.00 |
| | Malaria Ecology | 0.74 | 0.22 | 757.00 |
| Sierra Leone | Years | 2.29 | 1.67 | 8199.00 |
| | Grade | 3.25 | 1.68 | 8205.00 |
| | Delay | 0.39 | 0.49 | 8205.00 |
| | Age | 9.88 | 3.16 | 8206.00 |
| | Exposure | 0.25 | 0.09 | 8206.00 |
| | Malaria Ecology | 0.71 | 0.16 | 351.00 |
| Tanzania | Years | 3.34 | 2.10 | 21125.00 |
| | Grade | 3.83 | 2.04 | 10898.00 |
| | Delay | 0.33 | 0.47 | 10898.00 |
| | Age | 10.99 | 2.77 | 21127.00 |
| | Exposure | 0.59 | 0.13 | 21127.00 |
| | Malaria Ecology | 0.51 | 0.18 | 1080.00 |
| Uganda | Years | 2.44 | 1.92 | 35236.00 |
| | Grade | 3.32 | 2.63 | 35254.00 |
| | Delay | 0.41 | 0.49 | 35254.00 |
| | Age | 10.78 | 3.24 | 35257.00 |
| | Exposure | 0.26 | 0.22 | 35257.00 |
| | Malaria Ecology | 0.69 | 0.24 | 1070.00 |
| Zambia | Years | 2.74 | 1.96 | 8079.00 |
| | Grade | 3.70 | 1.95 | 8083.00 |
| | Delay | 0.34 | 0.47 | 8083.00 |
| | Age | 10.91 | 2.95 | 8083.00 |
| | Exposure | 0.40 | 0.12 | 8083.00 |
| | Malaria Ecology | 0.72 | 0.11 | 319.00 |
| Zimbabwe | Years | 3.00 | 2.05 | 24215.00 |
| | Grade | 3.82 | 2.09 | 24224.00 |
| | Delay | 0.32 | 0.47 | 24224.00 |
| | Age | 9.91 | 2.51 | 24225.00 |
| | Exposure | 0.26 | 0.32 | 24225.00 |
| | Malaria Ecology | 0.71 | 0.19 | 1042.00 |

**Table 3**: Quasi-experimental OLS results of malaria ecology and GF exposure

| | Years | | | | Grade | | | | Delay | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Burkina Faso | 48.869*** | 46.653*** | 187.582*** | 196.851*** | 48.747*** | 46.696*** | 186.760*** | 197.074*** | -13.396*** | -12.262*** | -50.608*** | -53.978*** |
| | (5.578) | (5.459) | (17.808) | (5.555) | (21.140) | (5.427) | (18.053) | (1.502) | (21.875) | (1.476) | (4.618) | (5.742) |
| R2 | 0.688 | 0.691 | 0.697 | 0.699 | 0.673 | 0.676 | 0.682 | 0.685 | 0.560 | 0.564 | 0.570 | 0.573 |
| Observations | 16176 | 16176 | 16176 | 16176 | 16177 | 16177 | 16177 | 16177 | 16177 | 16177 | 16177 | 16177 |
| Burundi | 0.102 | 0.537 | 2.269 | 5.351 | 0.163 | 0.694 | 1.492 | 4.990 | -0.131 | -0.168 | -0.568 | -1.826 |
| | (0.711) | (0.773) | (3.234) | (3.356) | (0.690) | (0.755) | (3.101) | (3.260) | (0.209) | (0.238) | (1.056) | (1.132) |
| R2 | 0.707 | 0.707 | 0.707 | 0.708 | 0.704 | 0.704 | 0.704 | 0.705 | 0.566 | 0.566 | 0.566 | 0.567 |
| Observations | 9113 | 9113 | 9113 | 9113 | 9110 | 9110 | 9110 | 9110 | 9110 | 9110 | 9110 | 9110 |
| Cameroon | 30.781*** | 35.714*** | 42.998*** | 33.600*** | 31.935*** | 36.813*** | 45.718*** | 37.311*** | -13.914*** | -14.626*** | -17.252*** | -15.931*** |
| | (2.407) | (2.498) | (2.674) | (2.794) | (2.434) | (2.512) | (3.150) | (3.389) | (0.606) | (0.616) | (0.634) | (0.708) |
| R2 | 0.665 | 0.668 | 0.669 | 0.672 | 0.612 | 0.615 | 0.616 | 0.619 | 0.552 | 0.556 | 0.557 | 0.559 |
| Observations | 26673 | 26673 | 26673 | 26673 | 26675 | 26675 | 26675 | 26675 | 26675 | 26675 | 26675 | 26675 |
| DRC | 3.837 | -5.599 | 1.255 | -13.617 | 3.720 | -4.975 | 6.283 | -14.529 | 1.145 | 2.246 | -4.531 | 7.368* |
| | (6.170) | (6.024) | (13.378) | (13.896) | (5.066) | (5.054) | (12.218) | (12.827) | (1.604) | (1.646) | (3.987) | (4.237) |
| R2 | 0.590 | 0.594 | 0.594 | 0.596 | 0.595 | 0.600 | 0.600 | 0.602 | 0.491 | 0.492 | 0.492 | 0.497 |
| Observations | 8836 | 8836 | 8836 | 8836 | 8847 | 8847 | 8847 | 8847 | 8847 | 8847 | 8847 | 8847 |
| Ethiopia | 1.200** | 5.576*** | 8.484*** | 8.966*** | 1.304*** | 5.674*** | 8.634*** | 9.223*** | -1.210*** | -2.908*** | -4.921*** | -5.695*** |
| | (0.490) | (0.708) | (0.859) | (1.029) | (0.488) | (0.705) | (0.855) | (1.025) | (0.113) | (0.177) | (0.211) | (0.303) |
| R2 | 0.548 | 0.555 | 0.556 | 0.557 | 0.547 | 0.554 | 0.554 | 0.556 | 0.395 | 0.404 | 0.409 | 0.412 |
| Observations | 33548 | 33548 | 33548 | 33548 | 33546 | 33546 | 33546 | 33546 | 33546 | 33546 | 33546 | 33546 |
| Ghana | 7.259*** | 6.196*** | 13.990*** | 17.122*** | 7.275*** | 6.195*** | 13.950*** | 17.048*** | -3.656*** | -3.302*** | -5.929*** | -6.840*** |
| | (0.937) | (0.936) | (1.322) | (1.326) | (0.952) | (0.944) | (1.302) | (1.308) | (0.298) | (0.298) | (0.391) | (0.381) |
| R2 | 0.599 | 0.607 | 0.609 | 0.604 | 0.593 | 0.600 | 0.602 | 0.597 | 0.476 | 0.482 | 0.485 | 0.481 |
| Observations | 13043 | 13043 | 13043 | 13043 | 13043 | 13043 | 13043 | 13043 | 13043 | 13043 | 13043 | 13043 |
| Guinea | 9.332** | 5.076 | 12.255 | -11.252 | 7.412 | 2.667 | 13.383 | -8.863 | -0.658 | -0.560 | -5.681 | 0.739 |
| | (4.588) | (4.882) | (14.054) | (14.427) | (4.603) | (4.900) | (14.022) | (14.360) | (1.364) | (1.448) | (4.136) | (4.217) |
| R2 | 0.630 | 0.630 | 0.630 | 0.633 | 0.626 | 0.626 | 0.629 | 0.626 | 0.502 | 0.502 | 0.502 | 0.502 |
| Observations | 5667 | 5667 | 5667 | 5667 | 5667 | 5667 | 5667 | 5667 | 5667 | 5667 | 5667 | 5667 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kenya | 3.038*** | 0.725 | 2.466* | 4.240*** | 2.174* | -0.010 | 2.001 | 4.040** | -4.162*** | -3.245*** | -5.320*** | -5.538*** |
| | (0.915) | (1.061) | (1.349) | (1.559) | (1.143) | (1.172) | (1.425) | (1.640) | (0.222) | (0.311) | (0.366) | (0.414) |
| R2 | 0.733 | 0.738 | 0.738 | 0.740 | 0.665 | 0.670 | 0.670 | 0.671 | 0.509 | 0.530 | 0.533 | 0.538 |
| Observations | 18669 | 18669 | 18669 | 18669 | 18672 | 18672 | 18672 | 18672 | 18672 | 18672 | 18672 | 18672 |
| Liberia | 3.354** | 2.912 | 1.556 | -1.765 | 2.870* | 2.385 | 1.745 | -2.115 | -0.116 | -0.463 | -0.675 | -0.020 |
| | (1.652) | (2.259) | (3.217) | (4.247) | (1.689) | (2.270) | (3.313) | (4.286) | (0.504) | (0.682) | (0.994) | (1.348) |
| R2 | 0.446 | 0.449 | 0.449 | 0.453 | 0.464 | 0.465 | 0.465 | 0.468 | 0.355 | 0.357 | 0.357 | 0.361 |
| Observations | 3231 | 3231 | 3231 | 3231 | 3228 | 3228 | 3228 | 3228 | 3228 | 3228 | 3228 | 3228 |
| Madagascar | 0.338 | -0.532 | -0.773 | -2.015 | 0.117 | -0.647 | -3.137 | -2.976* | -0.167 | 0.056 | 0.452 | 1.276** |
| | (0.334) | (0.379) | (1.439) | (1.563) | (0.458) | (0.411) | (2.415) | (1.780) | (0.115) | (0.133) | (0.516) | (0.561) |
| R2 | 0.624 | 0.631 | 0.631 | 0.633 | 0.417 | 0.421 | 0.421 | 0.423 | 0.513 | 0.517 | 0.517 | 0.521 |
| Observations | 17268 | 17268 | 17268 | 17268 | 17275 | 17275 | 17275 | 17275 | 17275 | 17275 | 17275 | 17275 |
| Malawi | 1.462*** | 0.325 | 0.549 | 1.896*** | 1.727*** | 0.689** | 1.627*** | 2.840*** | -2.282*** | -2.211*** | -4.937*** | -4.968*** |
| | (0.318) | (0.325) | (0.517) | (0.507) | (0.311) | (0.318) | (0.508) | (0.499) | (0.091) | (0.097) | (0.132) | (0.125) |
| R2 | 0.704 | 0.705 | 0.705 | 0.704 | 0.702 | 0.703 | 0.703 | 0.702 | 0.549 | 0.549 | 0.558 | 0.558 |
| Observations | 48856 | 48856 | 48856 | 48856 | 48856 | 48856 | 48862 | 48862 | 48862 | 48862 | 48862 | 48862 |
| Mali | 51.184*** | 187.538*** | 206.716*** | 254.281*** | 58.256*** | 200.169*** | 220.339*** | 272.033*** | -31.642*** | -89.710*** | -97.906*** | -125.869*** |
| | (6.680) | (14.004) | (13.713) | (15.557) | (6.867) | (14.536) | (14.080) | (15.883) | (2.148) | (5.454) | (4.933) | (4.655) |
| R2 | 0.653 | 0.660 | 0.661 | 0.664 | 0.655 | 0.663 | 0.664 | 0.666 | 0.524 | 0.542 | 0.544 | 0.551 |
| Observations | 14716 | 14716 | 14716 | 14716 | 14724 | 14724 | 14724 | 14724 | 14724 | 14724 | 14724 | 14724 |
| Mozambique | -1.318 | 0.909 | 11.163** | 14.265*** | -0.161 | 1.273 | 11.425** | 12.495*** | -0.380 | -0.275 | -3.483*** | -3.324** |
| | (0.965) | (0.972) | (4.851) | (4.688) | (0.944) | (0.956) | (4.648) | (4.336) | (0.258) | (0.272) | (1.263) | (1.296) |
| R2 | 0.685 | 0.692 | 0.692 | 0.694 | 0.694 | 0.700 | 0.700 | 0.702 | 0.546 | 0.547 | 0.547 | 0.548 |
| Observations | 14100 | 14100 | 14100 | 14100 | 14099 | 14099 | 14099 | 14099 | 14099 | 14099 | 14099 | 14099 |
| Namibia | 4.282*** | 3.197*** | 0.821 | 3.806*** | 4.252*** | 3.194*** | 0.861 | 3.906*** | -1.485*** | -2.614*** | -2.496*** | -3.151*** |
| | (0.434) | (0.703) | (0.749) | (0.832) | (0.433) | (0.688) | (0.730) | (0.818) | (0.111) | (0.197) | (0.207) | (0.223) |
| R2 | 0.716 | 0.719 | 0.720 | 0.723 | 0.721 | 0.724 | 0.725 | 0.728 | 0.568 | 0.579 | 0.579 | 0.583 |
| Observations | 14983 | 14983 | 14983 | 14983 | 14990 | 14990 | 14990 | 14990 | 14990 | 14990 | 14990 | 14990 |
| Nigeria | 20.747*** | 57.023*** | 85.462*** | 88.194*** | 28.045*** | 68.822*** | 100.756*** | 105.306*** | -16.285*** | -28.029*** | -36.988*** | -41.759*** |
| | (3.159) | (4.123) | (4.647) | (5.189) | (3.382) | (4.541) | (5.471) | (5.737) | (0.866) | (1.166) | (1.208) | (1.420) |
| R2 | 0.548 | 0.553 | 0.556 | 0.557 | 0.469 | 0.475 | 0.478 | 0.479 | 0.422 | 0.429 | 0.433 | 0.435 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observations | 28886 | 28886 | 28886 | 28886 | 28894 | 28894 | 28894 | 28894 | 28894 | 28894 | 28894 | 28894 |
| Rwanda | 0.513*** | 0.575*** | 1.006*** | 1.559*** | 0.447*** | 0.460*** | 0.827*** | 1.337*** | -0.825*** | -0.755*** | -1.107*** | -1.182*** |
| | (0.175) | (0.186) | (0.238) | (0.246) | (0.168) | (0.178) | (0.233) | (0.237) | (0.050) | (0.051) | (0.067) | (0.066) |
| R2 | 0.690 | 0.692 | 0.692 | 0.694 | 0.670 | 0.671 | 0.671 | 0.674 | 0.545 | 0.549 | 0.550 | 0.555 |
| Observations | 24887 | 24887 | 24887 | 24887 | 24921 | 24921 | 24921 | 24921 | 24921 | 24921 | 24921 | 24921 |
| Senegal | -0.233 | -1.207 | -13.835*** | -15.220*** | -0.879 | -1.937 | -17.447*** | -18.989*** | 1.270*** | 1.535*** | 7.888*** | 7.242*** |
| | (0.912) | (0.994) | (2.049) | (2.295) | (1.069) | (1.252) | (2.416) | (3.013) | (0.246) | (0.276) | (0.645) | (0.750) |
| R2 | 0.623 | 0.625 | 0.626 | 0.627 | 0.352 | 0.354 | 0.354 | 0.356 | 0.516 | 0.518 | 0.522 | 0.524 |
| Observations | 20978 | 20978 | 20978 | 20978 | 20991 | 20991 | 20991 | 20991 | 20991 | 20991 | 20991 | 20991 |
| Sierra Leone | 2.432*** | 1.415 | 1.775 | -1.393 | 2.427*** | 1.868* | 1.833 | -0.668 | -0.520* | -0.413 | -0.555 | 0.506 |
| | (0.839) | (1.024) | (2.433) | (2.924) | (0.866) | (1.019) | (2.434) | (2.891) | (0.266) | (0.316) | (0.764) | (0.886) |
| R2 | 0.599 | 0.600 | 0.600 | 0.601 | 0.602 | 0.603 | 0.603 | 0.604 | 0.496 | 0.496 | 0.496 | 0.497 |
| Observations | 8199 | 8199 | 8199 | 8199 | 8205 | 8205 | 8205 | 8205 | 8205 | 8205 | 8205 | 8205 |
| Tanzania | -0.629** | -0.383 | 0.420 | 4.331** | -1.223** | -1.348** | -6.051** | 4.492 | -0.202* | 0.294* | 2.404*** | -0.151 |
| | (0.311) | (0.396) | (1.057) | (2.129) | (0.483) | (0.653) | (2.647) | (4.022) | (0.123) | (0.161) | (0.686) | (1.030) |
| R2 | 0.773 | 0.776 | 0.776 | 0.777 | 0.761 | 0.763 | 0.763 | 0.764 | 0.578 | 0.582 | 0.582 | 0.585 |
| Observations | 21124 | 21124 | 21124 | 21124 | 10898 | 10898 | 10898 | 10898 | 10898 | 10898 | 10898 | 10898 |
| Uganda | -0.948*** | -0.343 | -0.024 | -0.362 | -0.658 | -0.271 | -0.595 | -0.774 | -0.484*** | -0.687*** | -0.785*** | -0.654*** |
| | (0.318) | (0.318) | (0.427) | (0.430) | (0.541) | (0.466) | (0.748) | (0.725) | (0.092) | (0.095) | (0.118) | (0.117) |
| R2 | 0.706 | 0.708 | 0.708 | 0.706 | 0.497 | 0.498 | 0.498 | 0.497 | 0.529 | 0.531 | 0.531 | 0.529 |
| Observations | 35236 | 35236 | 35236 | 35236 | 35253 | 35253 | 35253 | 35253 | 35253 | 35253 | 35253 | 35253 |
| Zambia | -0.142 | 0.400 | -6.845** | -4.113 | -0.295 | 0.151 | -6.180** | -3.346 | -0.262 | -0.178 | 1.379 | 0.630 |
| | (1.022) | (1.070) | (2.988) | (3.074) | (0.972) | (1.027) | (2.878) | (2.867) | (0.294) | (0.303) | (0.879) | (0.854) |
| R2 | 0.698 | 0.700 | 0.700 | 0.701 | 0.699 | 0.701 | 0.701 | 0.702 | 0.538 | 0.538 | 0.539 | 0.542 |
| Observations | 8079 | 8079 | 8079 | 8079 | 8083 | 8083 | 8083 | 8083 | 8083 | 8083 | 8083 | 8083 |
| Zimbabwe | 1.223** | 2.075*** | 1.741*** | 2.513*** | 1.883*** | 2.781*** | 2.663*** | 3.268*** | -2.042*** | -2.387*** | -2.977*** | -3.350*** |
| | (0.485) | (0.537) | (0.623) | (0.691) | (0.495) | (0.560) | (0.649) | (0.729) | (0.130) | (0.163) | (0.167) | (0.181) |
| R2 | 0.765 | 0.765 | 0.765 | 0.767 | 0.702 | 0.703 | 0.703 | 0.704 | 0.590 | 0.596 | 0.597 | 0.600 |
| Observations | 24215 | 24215 | 24215 | 24215 | 24224 | 24224 | 24224 | 24224 | 24224 | 24224 | 24224 | 24224 |

*Notes*: This table presents OLS results with cluster-robust standard errors for dependent variables years of schooling, current grade level, and delay status. Column 1 includes fixed effects for year of birth, DHS cluster, and DHS survey year. Column 2 adds an interaction between regional dummy variables and Global Fund exposure. Column 3 adds an interaction between age and malaria ecology. Column 4 adds an interaction between regional dummy variables and date of birth. All columns control for gender, wealth, and age. Standard errors are in parentheses. *, ** and *** indicate significance at the 10, 5 and 1% levels.

**Table 4**: 2SLS results using G6PD deficiency and basic reproductive number under control as instruments for malaria ecology

| | Years | Grade | Delay |
|---|---|---|---|
| | (1) | (2) | (3) |
| Burkina Faso | 371.135*** (24.140) | 377.989*** (23.679) | -92.645*** (5.947) |
| R2 | 0.703 | 0.690 | 0.577 |
| Observations | 15447 | 15448 | 15448 |
| Burundi | 102.837 (92.499) | 121.762 (95.135) | -68.510* (38.544) |
| R2 | 0.672 | 0.655 | 0.388 |
| Observations | 8160 | 8157 | 8157 |
| Cameroon | 57.378*** (4.099) | 59.733*** (4.264) | -22.669*** (1.065) |
| R2 | 0.668 | 0.616 | 0.557 |
| Observations | 26568 | 26570 | 26570 |
| DRC | 226.192 (502.131) | 6.356 (561.569) | 176.166 (192.814) |
| R2 | 0.595 | 0.603 | 0.443 |
| Observations | 8414 | 8424 | 8424 |
| Ethiopia | 14.325*** (1.661) | 14.423*** (1.651) | -11.275*** (0.363) |
| R2 | 0.565 | 0.565 | 0.414 |
| Observations | 26920 | 26919 | 26919 |
| Ghana | 30.732*** (2.069) | 31.049*** (2.090) | -12.772*** (0.571) |
| R2 | 0.608 | 0.601 | 0.482 |
| Observations | 12827 | 12827 | 12827 |
| Guinea | -71.944 (456.491) | -87.485 (452.924) | 201.353 (147.728) |
| R2 | 0.630 | 0.625 | 0.404 |
| Observations | 5561 | 5561 | 5561 |
| Kenya | -22.138*** (7.435) | -15.320** (7.214) | 0.096 (1.672) |
| R2 | 0.727 | 0.651 | 0.543 |
| Observations | 15893 | 15896 | 15896 |
| Liberia | -3.249 (7.427) | -0.855 (7.671) | 3.027 (2.796) |
| R2 | 0.449 | 0.465 | 0.355 |
| Observations | 3231 | 3228 | 3228 |
| Madagascar | -21.187** (8.515) | -16.024 (11.879) | 6.610** (3.049) |
| R2 | 0.629 | 0.416 | 0.516 |
| Observations | 16557 | 16564 | 16564 |
| Malawi | 1.058 (0.824) | 2.402*** (0.808) | -8.991*** (0.153) |
| R2 | 0.705 | 0.702 | 0.557 |
| Observations | 47956 | 47962 | 47962 |
| Mali | 269.381*** (15.340) | 285.259*** (15.249) | -133.560*** (4.152) |
| R2 | 0.660 | 0.663 | 0.547 |
| Observations | 14367 | 14375 | 14375 |
| Mozambique | 61.494 (58.527) | 42.610 (55.291) | -10.986 (13.613) |
| R2 | 0.689 | 0.699 | 0.546 |
| Observations | 14075 | 14074 | 14074 |
| Namibia | 8.069*** (1.245) | 8.268*** (1.254) | -4.483*** (0.328) |
| R2 | 0.705 | 0.707 | 0.562 |

| | | | |
|---|---|---|---|
| Observations | 10964 | 10967 | 10967 |
| Nigeria | 112.645*** (8.694) | 126.450*** (9.230) | -50.700*** (2.328) |
| R2 | 0.556 | 0.478 | 0.432 |
| Observations | 28831 | 28839 | 28839 |
| Rwanda | 2.090*** (0.369) | 1.747*** (0.363) | -2.012*** (0.106) |
| R2 | 0.694 | 0.673 | 0.550 |
| Observations | 19133 | 19155 | 19155 |
| Senegal | -21.146*** (3.982) | -20.882*** (6.580) | 15.461*** (1.179) |
| R2 | 0.627 | 0.352 | 0.521 |
| Observations | 20570 | 20583 | 20583 |
| Sierra Leone | -47.208 (35.027) | -37.302 (34.014) | 9.806 (10.169) |
| R2 | 0.583 | 0.591 | 0.486 |
| Observations | 8141 | 8147 | 8147 |
| Tanzania | 0.916 (1.399) | -2.112 (7.197) | 2.757 (1.921) |
| R2 | 0.776 | 0.764 | 0.582 |
| Observations | 20249 | 10511 | 10511 |
| Uganda | 3.195*** (0.982) | 2.296 (1.760) | -2.541*** (0.273) |
| R2 | 0.708 | 0.485 | 0.527 |
| Observations | 31493 | 31510 | 31510 |
| Zambia | -145.021* (74.212) | -145.208** (73.801) | -1.740 (9.495) |
| R2 | 0.645 | 0.644 | 0.538 |
| Observations | 8079 | 8083 | 8083 |
| Zimbabwe | 6.781*** (1.076) | 8.467*** (1.215) | -6.752*** (0.234) |
| R2 | 0.765 | 0.701 | 0.596 |
| Observations | 23596 | 23604 | 23604 |

*Notes*: This table presents 2SLS results with cluster-robust standard errors for dependent variables years of schooling, current grade level, and delay status. All estimations include fixed effects for year of birth, DHS cluster, and DHS survey year. All columns also control for an interaction between regional dummy variables and Global Fund exposure, an interaction between age and malaria ecology, gender, age, and wealth. Standard errors are in parentheses. *, ** and *** indicate significance at the 10, 5 and 1% levels.

**Table 5**: Quasi-experimental OLS results with entomological inoculation rate as an alternative malaria ecology measure

| | Years | Grade | Delay |
|---|---|---|---|
| | (1) | (2) | (3) |
| Burkina Faso | 2.639*** (0.264) | 2.645*** (0.261) | -0.529*** (0.066) |
| R2 | 0.689 | 0.675 | 0.562 |
| Observations | 15447 | 15448 | 15448 |
| Burundi | 1.959*** (0.542) | 1.944*** (0.542) | -0.354* (0.192) |
| R2 | 0.705 | 0.704 | 0.566 |
| Observations | 8160 | 8157 | 8157 |
| Cameroon | 0.462*** (0.049) | 0.441*** (0.051) | -0.072*** (0.015) |
| R2 | 0.665 | 0.612 | 0.548 |
| Observations | 26568 | 26570 | 26570 |
| DRC | 6.577*** (0.877) | 6.366*** (0.829) | -1.512*** (0.253) |
| R2 | 0.601 | 0.605 | 0.498 |
| Observations | 8414 | 8424 | 8424 |
| Ethiopia | 32.164*** (3.620) | 32.468*** (3.598) | -21.171*** (0.944) |
| R2 | 0.567 | 0.566 | 0.422 |
| Observations | 26920 | 26919 | 26919 |
| Ghana | 0.190*** (0.050) | 0.168*** (0.051) | -0.091*** (0.016) |
| R2 | 0.609 | 0.602 | 0.480 |
| Observations | 12827 | 12827 | 12827 |
| Guinea | 2.419*** (0.899) | 2.625*** (0.881) | -0.997*** (0.336) |
| R2 | 0.632 | 0.628 | 0.503 |
| Observations | 5561 | 5561 | 5561 |
| Kenya | 0.013 (0.081) | 0.091 (0.083) | -0.010 (0.018) |
| R2 | 0.730 | 0.652 | 0.543 |
| Observations | 15893 | 15896 | 15896 |
| Liberia | 0.593*** (0.166) | 0.610*** (0.146) | -0.171*** (0.045) |
| R2 | 0.449 | 0.461 | 0.353 |
| Observations | 5241 | 5237 | 5237 |
| Madagascar | 0.165*** (0.052) | 0.212*** (0.061) | -0.029 (0.020) |
| R2 | 0.632 | 0.416 | 0.519 |
| Observations | 16557 | 16564 | 16564 |
| Malawi | 0.036* (0.018) | 0.041** (0.018) | -0.054*** (0.004) |
| R2 | 0.705 | 0.703 | 0.544 |
| Observations | 47956 | 47962 | 47962 |
| Mali | 1.879*** (0.424) | 1.980*** (0.420) | -0.827*** (0.123) |
| R2 | 0.652 | 0.653 | 0.523 |
| Observations | 14367 | 14375 | 14375 |
| Mozambique | 0.328*** (0.103) | 0.399*** (0.092) | 0.052** (0.025) |
| R2 | 0.692 | 0.700 | 0.547 |
| Observations | 14075 | 14074 | 14074 |
| Namibia | 7.368*** (1.321) | 7.148*** (1.346) | -3.599*** (0.344) |
| R2 | 0.706 | 0.708 | 0.559 |

| | | | |
|---|---|---|---|
| Observations | 10964 | 10967 | 10967 |
| Nigeria | 1.109*** (0.113) | 1.109*** (0.106) | -0.419*** (0.031) |
| R2 | 0.552 | 0.472 | 0.421 |
| Observations | 28831 | 28839 | 28839 |
| Rwanda | 1.985*** (0.673) | 1.934*** (0.666) | -3.014*** (0.205) |
| R2 | 0.694 | 0.674 | 0.552 |
| Observations | 19133 | 19155 | 19155 |
| Senegal | 0.918 (0.850) | 1.745* (1.009) | 0.037 (0.264) |
| R2 | 0.626 | 0.352 | 0.518 |
| Observations | 20570 | 20583 | 20583 |
| Sierra Leone | 0.351** (0.172) | 0.277 (0.169) | -0.078 (0.055) |
| R2 | 0.599 | 0.602 | 0.495 |
| Observations | 8141 | 8147 | 8147 |
| Tanzania | 0.046 (0.115) | -0.191 (0.203) | 0.107 (0.068) |
| R2 | 0.776 | 0.763 | 0.581 |
| Observations | 20249 | 10511 | 10511 |
| Uganda | 0.099*** (0.022) | 0.073** (0.035) | -0.038*** (0.006) |
| R2 | 0.708 | 0.485 | 0.527 |
| Observations | 31493 | 31510 | 31510 |
| Zambia | 1.650*** (0.495) | 1.729*** (0.493) | -0.460*** (0.113) |
| R2 | 0.701 | 0.701 | 0.539 |
| Observations | 8079 | 8083 | 8083 |
| Zimbabwe | 2.100** (0.890) | 1.845** (0.806) | -2.038*** (0.258) |
| R2 | 0.767 | 0.702 | 0.592 |
| Observations | 23596 | 23604 | 23604 |

*Notes*: This table presents OLS results with cluster-robust standard errors for dependent variables years of schooling, current grade level, and delay status. All estimations include fixed effects for year of birth, DHS cluster, and DHS survey year. All columns also control for an interaction between regional dummy variables and Global Fund exposure, an interaction between age and malaria ecology, gender, age, and wealth. Standard errors are in parentheses. *, ** and *** indicate significance at the 10, 5 and 1% levels.

**Table 6**: Quasi-experimental OLS results with Kiszewski et al.'s (2004) stability index as an alternative malaria ecology measure

| | Years | Grade | Delay |
|---|---|---|---|
| | (1) | (2) | (3) |
| Burkina Faso | 5.946*** (0.597) | 5.915*** (0.608) | -1.630*** (0.158) |
| R2 | 0.697 | 0.683 | 0.570 |
| Observations | 16176 | 16177 | 16177 |
| Burundi | -0.046 (0.201) | -0.115 (0.202) | 0.026 (0.062) |
| R2 | 0.707 | 0.704 | 0.566 |
| Observations | 9113 | 9110 | 9110 |
| Cameroon | 0.721*** (0.098) | 0.696*** (0.097) | -0.283*** (0.027) |
| R2 | 0.665 | 0.612 | 0.549 |
| Observations | 26673 | 26675 | 26675 |
| DRC | -0.034 (0.320) | 0.128 (0.305) | -0.168* (0.089) |
| R2 | 0.594 | 0.600 | 0.492 |
| Observations | 8836 | 8847 | 8847 |
| Ethiopia | 0.270*** (0.043) | 0.272*** (0.043) | -0.099*** (0.011) |
| R2 | 0.555 | 0.553 | 0.401 |
| Observations | 33548 | 33546 | 33546 |
| Ghana | 0.252*** (0.041) | 0.250*** (0.040) | -0.136*** (0.012) |
| R2 | 0.607 | 0.600 | 0.481 |
| Observations | 13043 | 13043 | 13043 |
| Guinea | 1.973*** (0.334) | 1.883*** (0.334) | -0.538*** (0.103) |
| R2 | 0.632 | 0.628 | 0.504 |
| Observations | 5667 | 5667 | 5667 |
| Kenya | -0.039 (0.039) | -0.033 (0.042) | -0.021** (0.009) |
| R2 | 0.739 | 0.670 | 0.527 |
| Observations | 18669 | 18672 | 18672 |
| Liberia | 0.099* (0.052) | 0.121** (0.052) | -0.029* (0.016) |
| R2 | 0.447 | 0.459 | 0.349 |
| Observations | 5384 | 5380 | 5380 |
| Madagascar | 0.128*** (0.047) | 0.209*** (0.069) | -0.065*** (0.019) |
| R2 | 0.631 | 0.421 | 0.518 |
| Observations | 17268 | 17275 | 17275 |
| Malawi | -0.001 (0.027) | 0.030 (0.027) | -0.112*** (0.006) |
| R2 | 0.705 | 0.703 | 0.545 |
| Observations | 48856 | 48862 | 48862 |
| Mali | 3.918*** (0.317) | 4.212*** (0.319) | -1.961*** (0.100) |
| R2 | 0.658 | 0.660 | 0.536 |
| Observations | 14716 | 14724 | 14724 |
| Mozambique | 0.399*** (0.133) | 0.545*** (0.130) | 0.093*** (0.034) |
| R2 | 0.693 | 0.701 | 0.547 |
| Observations | 14100 | 14099 | 14099 |
| Namibia | 0.131** (0.065) | 0.122* (0.064) | -0.203*** (0.018) |
| R2 | 0.721 | 0.725 | 0.578 |

| | | | |
|---|---|---|---|
| Observations | 14983 | 14990 | 14990 |
| Nigeria | 1.881*** (0.119) | 2.201*** (0.140) | -0.809*** (0.034) |
| R2 | 0.554 | 0.476 | 0.428 |
| Observations | 28886 | 28894 | 28894 |
| Rwanda | -0.154** (0.077) | -0.122 (0.076) | -0.072*** (0.023) |
| R2 | 0.692 | 0.671 | 0.546 |
| Observations | 24887 | 24921 | 24921 |
| Senegal | -0.376*** (0.087) | -0.575*** (0.109) | 0.270*** (0.026) |
| R2 | 0.625 | 0.354 | 0.521 |
| Observations | 20978 | 20991 | 20991 |
| Sierra Leone | 0.137*** (0.051) | 0.123** (0.052) | -0.032** (0.016) |
| R2 | 0.600 | 0.603 | 0.497 |
| Observations | 8199 | 8205 | 8205 |
| Tanzania | -0.002 (0.050) | -0.235*** (0.069) | 0.097*** (0.020) |
| R2 | 0.776 | 0.763 | 0.583 |
| Observations | 21124 | 10898 | 10898 |
| Uganda | 0.079*** (0.023) | 0.092*** (0.024) | -0.013** (0.006) |
| R2 | 0.708 | 0.498 | 0.531 |
| Observations | 35236 | 35254 | 35254 |
| Zambia | 0.306** (0.132) | 0.334** (0.131) | -0.129*** (0.033) |
| R2 | 0.700 | 0.701 | 0.539 |
| Observations | 8079 | 8083 | 8083 |
| Zimbabwe | 0.132*** (0.051) | 0.194*** (0.052) | -0.133*** (0.013) |
| R2 | 0.766 | 0.704 | 0.591 |
| Observations | 24215 | 24224 | 24224 |

*Notes*: This table presents OLS results with cluster-robust standard errors for dependent variables years of schooling, current grade level, and delay status. All estimations include fixed effects for year of birth, DHS cluster, and DHS survey year. All columns also control for an interaction between regional dummy variables and Global Fund exposure, an interaction between age and malaria ecology, gender, age, and wealth. Standard errors are in parentheses. *, ** and *** indicate significance at the 10, 5 and 1% levels.